NACA

RESEARCH MEMORANDUM

FLIGHT MEASUREMENTS OF THE LOADS AND MOMENTS ON AN

EXTERNAL STORE MOUNTED UNDER THE WING OF A

SWEPT-WING FIGHTER-TYPE AIRPLANE DURING

YAWING AND ROLLING MANEUVERS

By Harold A. Hamer and Thomas C. O'Bryan

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SUMMARY

A flight investigation to determine the effects of maneuvering on external-store characteristics has been conducted with the use of a 245-gallon auxiliary fuel tank mounted under the wing of a North American F-86A airplane. The external-store normal- and side-load distributions, as well as the pylon side-load distributions, were measured by means of an integrating pressure system at speeds up to the maximum Mach number obtainable and at lift coefficients up to about the airplane buffet boundary. The results are presented in the form of aerodynamic load-coefficient distributions and their corresponding overall force and moment coefficients in conjunction with a brief summary of the inertia loads experienced by the store.

The results indicate that the effect of sideslip angle on the side forces and yawing moments on the store and pylon is of the same order of magnitude as that of the angle of attack or lift coefficient. With regard to angular motions it is indicated that there is little or no effect of yawing or pitching velocity on the external-store aerodynamic loads. The aerodynamic effect of rolling velocity on the side forces and yawing moments on the store and pylon, in which the direction of the wing from which the store is suspended is downward, is primarily attributed to the increased lift coefficient due to the induced angle of attack at the store. For rolling velocity in which the direction of the wing is upward the aero-dynamic effect on the normal and side loads is negligible.

It is shown that during rolling-type maneuvers with a fully loaded store the inertia effects on the store normal and side loads would generally be greater than the aerodynamic effects.

INTRODUCTION

     The design of external store installations has been hampered because
of lack of sufficient information on the loads imposed during flight.
Some wind-tunnel data are available on the forces and moments measured
on external stores mounted under swept wings. (For example, see refs. 1
and 2.) In these tests the effects of airplane lift coefficient and side-
slip angle have been investigated; however, the effects of yawing and
rolling velocities could not be determined.

     Consequently, the National Advisory Committee for Aeronautics has
conducted a limited flight investigation of the aerodynamic forces and
moments on a 245-gallon auxiliary fuel tank and pylon mounted under the
wing of a North American F-86A airplane. Reference 3 presents the effect
of airplane lift coefficient on the loads as obtained during wind-up
turns, where the angle of attack was increased up to the attainment of
heavy buffeting. An analysis of the buffeting characteristics of this
store is presented in reference 4. The present paper expands the scope
of this investigation to include the effects of sideslip and airplane
angular motions on the steady loads on the tank and pylon.

     Measurements were made during continuous sideslips, rudder kicks,
and abrupt rolls performed at speeds up to the maximum Mach number obtain-
able and at lift coefficients up to about the airplane buffet boundary.
Results are shown as aerodynamic load-coefficient distributions and their
integrated force and moment coefficients. The inertia loads inherent
during these type maneuvers are also discussed briefly.

SYMBOLS

A_s area represented by each pressure measurement on store and
              stabilizing fins (that part of total projected area in plane
              normal to measurement included between lines lying midway to
              the adjacent stations), sq ft

A_p area represented by each pressure measurement on pylon (that
              part of total projected area in plane normal to measurement
              included between lines lying midway to the adjacent stations),
              sq ft

b   wing span, ft

c   pylon chord in the stream direction

C_L airplane lift coefficient, nW/qS

c_{n_S} section normal-load coefficient on store and stabilizing fins,

$$\frac{p_{U_{av}} - p_{L_{av}}}{q}$$

c_{y_S} section side-load coefficient on store, $\left(\dfrac{p_{OB_{av}} - p_{IB_{av}}}{q}\right)_{Store}$

c_{y_p} section side-load coefficient on pylon, $\left(\dfrac{p_{OB_{av}} - p_{IB_{av}}}{q}\right)_{Pylon}$

C_{N_S} normal-force coefficient on store and stabilizing fins,

$$\frac{\sum (c_{n_S} A_S)}{S_S}$$

C_{Y_S} side-force coefficient on store, $\dfrac{\sum \left(c_{y_S} A_S\right)}{S_S}$

C_{Y_p} side-force coefficient on pylon, $\dfrac{\sum \left(c_{y_p} A_p\right)}{S_S}$

C_{m_S} pitching-moment coefficient on store and stabilizing fins,

$$\frac{\sum \left(c_{n_S} A_S l_c\right)}{S_S l_m}$$

C_{n_S} yawing-moment coefficient on store, $\dfrac{\sum \left(c_{y_S} A_S l_c\right)}{S_S l_m}$

C_{n_p} yawing-moment coefficient on pylon, $\dfrac{\sum \left(c_{y_p} A_p l_c\right)}{S_S l_m}$

D_{MAX} maximum diameter of store

h_p maximum vertical dimension of pylon at any longitudinal station

h_s maximum vertical dimension of store at any longitudinal station

l_c distance from center of gravity of store to centroid of area represented by each pressure measurement on store, stabilizing fins, or pylon, ft

l_m maximum length of store, ft

l_p longitudinal dimension of pylon

l_s longitudinal dimension of store

m   mass of fully loaded store

M   Mach number

N_S normal force on store and stabilizing fins, lb

n   airplane normal load factor

n_T airplane transverse or lateral load factor

p   airplane rolling angular velocity, radians/sec

$\dot{p}$ airplane rolling angular acceleration, radians/sec^2

$p_{U_{av}}$ average pressure over upper circumference at any cross-section measuring station, lb/ft^2

$p_{L_{av}}$ average pressure over lower circumference at any cross-section measuring station, lb/ft^2

$p_{IB_{av}}$ average pressure over inboard circumference at any cross-section measuring station, lb/ft^2

$p_{OB_{av}}$ average pressure over outboard circumference at any cross-section measuring station, lb/ft^2

q   dynamic pressure, $\frac{1}{2}\rho V^2$, lb/ft^2

r   airplane yawing angular velocity, radians/sec

S   total wing area, sq ft

S_S maximum cross-section frontal area of store, sq ft

t   maximum thickness of pylon

V   true airspeed, ft/sec

W   airplane gross weight, lb

w_p maximum transverse dimension of pylon at any longitudinal station

w_s maximum transverse dimension of store at any longitudinal station

x   longitudinal distance from nose of store, ft

y   lateral distance of store from airplane center line, ft

Y_s side force on store, lb

α   airplane angle of attack, deg

β   airplane angle of sideslip, deg

Δ   increment

ρ   mass density of air, slugs/cu ft

TEST APPARATUS

Airplane and External Store

A photograph of the external store installed under the 35° sweptback wing of the F-86A airplane is presented as figure 1. Details and dimensions of the airplane and store installation are shown in figures 2 and 3. Additional dimensions and physical characteristics of the airplane, store, and pylon are presented in table I.

The external store used was a 245-gallon auxiliary fuel tank manufactured by North American Aviation, Inc. The tank is generally elliptical in shape and has a fineness ratio of about 5. Small horizontal stabilizing fins are attached at the tail of the tank. The fittings from which the tank is mounted are enclosed by a fairing which is denoted in this paper as the pylon. During these tests the weight of the tank, which was empty except for instrumentation was about 275 pounds, or approximately one-fifth that of the tank with the rated amount of fuel.

Instrumentation

Normal and side components of the air load on the tank, as well as the side component on the pylon, were measured at each of the stations shown in figure 4 with the use of an integrating pressure system. Details of a typical measuring station as applied to determining normal load are also shown in figure 4. In this case the system integrated separately the pressures from orifices on the upper and lower circumference of the tank and the difference was recorded by standard NACA pressure recorders. Side loads on the tank and on the pylon were determined in a similar fashion by utilizing other sets of orifices. Additional information on the operation of the system is presented in reference 3.

Standard NACA recording instruments were used to measure the quantities defining the flight conditions and airplane motions. All recorders including the pressure recorders were synchronized by means of a common timing circuit.

Mach number and pressure altitude were measured with the use of a calibrated nose-boom airspeed installation. Mach numbers obtained by this method are estimated to be accurate within ±0.01.

Airplane angular velocities were recorded about three mutually perpendicular axes in which the longitudinal reference axis is the one commonly used for leveling the airplane. The normal load factor was measured by an NACA air-damped recording accelerometer located near the airplane center of gravity.

Sideslip angle was measured by the use of a vane which was mounted above the nose of the fuselage, approximately midway between the inlet and windshield. The angle of sideslip is defined herein as the angle between the longitudinal axis and the projection of the relative wind in the horizontal plane of the airplane. Measurements transmitted by the vane were corrected for position error with the use of data presented in reference 5. The measurements were also corrected for effects induced by yawing and rolling velocities. The estimated accuracy of the corrected values of sideslip angle is within ±0.3°.

TEST PROCEDURE

In general, the tests were performed at pressure altitudes of approximately 20,000 and 30,000 feet at three Mach numbers selected so as to be representative of the store loading throughout the speed range. For the two lower Mach numbers which were about 0.55 and 0.78, maneuvers were made at lift coefficients up to the airplane buffet boundary. For the highest Mach number 0.86, which is about the maximum obtainable for the airplane

with the test tanks on, only a small range of lift coefficients was
obtained. At this Mach number a type of buffeting which is excited at
the tanks is experienced at any level of lift coefficient. The buffet
boundary and a description of the buffeting characteristics for this
particular installation are presented in reference 4.

The type of maneuvers consisted of continuous sideslips, rudder
kicks, and abrupt aileron rolls. In the continuous sideslips the side-
slip angle was gradually varied between approximately the maximum right
and left values obtainable in this type of maneuver. The values of yawing
velocity and rolling velocity developed during the rudder kicks and aileron
rolls, respectively, were approximately the maximum obtainable in controlled
flight. Lift coefficient was varied by performing the aforementioned
maneuvers during a number of steady turns at various load factors. The
difficulty of performing the required maneuvers at high Mach numbers
limited the range of lift coefficients investigated for the Mach number
of 0.86.

RESULTS AND DISCUSSION

Normal- and Side-Load Distribution

Plots of typical normal- and side-load distributions on the store,
as well as side-load distributions on the pylon, are shown in figures 5
through 11. The distributions are in coefficient form and pertain to
loads measured on the store mounted under the right wing of the airplane.
Side loads to the right are referred to as acting outboard, and to the
left as acting inboard.

It will be noted that for the store normal loads the distribution
on the fin is shown separately from that on the store itself. When buf-
feting was present the distributions represent mean values of the loads.

Variation of distributions with angle of attack.- Distributions of
section load coefficients over the store, fins, and pylon at a Mach num-
ber of 0.55 for three representative airplane angles of attack are pre-
sented in figure 5. The distributions shown for the two lower angles of
attack were obtained below the buffet boundary and the distributions
for $\alpha = 11.1^\circ$ $(C_L = 0.76)$, which are taken from reference 3, were
obtained during heavy buffeting. It can be seen that the side load dis-
tributions on the store and pylon, as well as the normal load distribu-
tions on the store, are considerably affected by angle of attack. The
variation of the side-load distributions on the store and pylon with
angle of attack is relatively systematic; however, there is a pronounced
difference in the variation of the store normal-load distributions with
angle of attack at the rear of the store and at the fins. The variation

of the load distributions on the store and pylon with angle of attack at
the higher Mach numbers is similar to that shown in figure 5, except when
high lift coefficients are reached at a Mach number of 0.86 which is dis-
cussed in the next section.

Variation of distributions with sideslip angle.- Distributions of
section normal-load coefficients on the store and fins, side-load coef-
ficients on the store, and side-load coefficients on the pylon are shown
in figures 6, 7, and 8, respectively, for three Mach numbers. For each
Mach number, the distributions are given for various sideslip angles and
are at constant airplane lift coefficients, except for the case of the
highest Mach number, 0.86. In this case, where buffeting is present for
any value of lift coefficient, an additional distribution is shown in
each figure for a much higher lift coefficient at a comparable sideslip
angle. This value of lift coefficient was obtained during a pitch-up into
severe buffeting.

It can be seen in figure 6 that the effect of sideslip angle on the
distributions of section normal-load coefficients is relatively small
and about the same at any Mach number.

In contrast the effect of sideslip angle on the store side-load
distributions, shown in figure 7, is seen to be considerably greater.
The distributions shown in figure 7 for a Mach number of 0.86 at the
low lift coefficient are different from the other distributions shown
in the figure in the vicinity of station x/l_m of 0.65.

. The effects of sideslip angle and Mach number on the pylon side-load
distributions (fig. 8) are essentially the same as those on the store
side-load distributions.

In comparing the two distributions for a Mach number of 0.86 and a
sideslip angle of 1° it is seen that the shape of the high lift coeffi-
cient distribution for the side loads on the store (fig. 7) and the pylon
(fig. 8) is quite different from that for the low lift coefficient. In
fact, the shape resembles that shown for the case of the high lift coef-
ficient for a low Mach number in figure 5. It is quite evident upon
examination of the two distributions of the side loads on the store in
figure 7 and on the pylon in figure 8 that there is little difference in
the magnitudes of the overall loads for the two cases. There is, however,
a large change in the yawing moments. As for the normal-load distribu-
tions at these two lift coefficients, it is evident from figure 6 that
the section normal-load coefficients are about the same over the rear
half of the store, with exception of those over the fins. The section
normal-load coefficients over the rear half of the store, itself, during
buffeting $(C_L = 0.76)$ at a Mach number of 0.55, which are shown in fig-
ure 5, are also about the same as those just discussed for a Mach number
of 0.86. It appears that when airplane angle of attack is varied during
buffeting only the distribution over the front portion of the store and
over the fins is primarily affected.

Variation of distributions with yawing, pitching, and rolling
velocity.- Examples of the effect of yawing velocity on the distributions
of section normal- and side-load coefficients are presented in figure 9
for two Mach numbers. (Nose right corresponds to positive yawing velocity.)
For each Mach number all conditions are the same except for the value of
yawing velocity; therefore, any difference in the distributions will be
entirely due to the yawing velocity effect. In figure 9(a) distributions
are compared for zero yawing velocity and for a yawing velocity of
0.20 radian per second which is about the maximum value obtainable in
controlled flight. In figure 9(b) the distributions are compared for
approximately equal values of positive and negative yawing velocity. For
the higher Mach numbers appropriate data for comparison were available
only at a Mach number of 0.83. As can be seen by the shape of the dis-
tributions this Mach number is below that for which the high-speed type
of buffeting occurs. Examination of the symbols in figure 9 shows the
effect of yawing velocity on the aerodynamic loads can be considered
negligible.

During the course of the tests pitching velocities as high as about
±0.20 radian per second were obtained. The effect of pitching velocity
on the store and pylon aerodynamic loads was found to be negligible.

An example of the positive rolling velocity effect on the right store
distributions of section normal- and side-load coefficients at a Mach num-
ber of 0.55 is presented in figure 10. A comparison is shown for a zero
rolling velocity and for a positive rolling velocity (right wing down)
of 2.25 radians per second, with all other flight conditions being the
same. In addition a set of distributions is shown for zero rolling veloc-
ity, but for a higher lift coefficient.

The effect of positive rolling velocity is noticeable upon examina-
tion of the two sets of distributions at the same lift coefficient. Fur-
thermore, the distributions vary with rolling velocity in a manner similar
to those shown for various airplane angles of attack in figure 5. It is
therefore indicated that the rolling velocity effect on the store aerody-
namic loads is primarily accounted for by the angle of attack induced at
the store by the rolling velocity. This is illustrated in figure 10 with
the use of the solid symbols which represent a set of distributions
obtained in flight for an airplane lift coefficient increased by the
amount induced at the store by the rolling velocity of 2.25 radians per
second. It can be seen for the side-load distributions on the store and
pylon that the rolling velocity effect is about equivalent to that pro-
duced by the increased angle of attack or lift coefficient. In the case
of the normal load, it is seen that the effect of rolling velocity on the
distribution is not entirely due to the induced angle of attack. This
discrepancy may be due to effects of the airload distribution over the
wing as well as local effects caused by the aileron, which is directly
above the rear of the store.

It was found that negative rolling velocity (right wing up) has little effect on the right store-load distributions, as illustrated in figure 11. This can be expected since the wing covers most of the store and would prevent any changes in load induced by negative rolling velocity. In figure 11(b) it can be seen that a negative rolling velocity of -0.80 radian per second does not materially change the side-load distributions on either the store or pylon and has only a slight effect on the normal-load distributions. For comparison, distributions are given in figure 11(a) to show that the effect of an equal and opposite value of rolling velocity is relatively large. The rolling velocity of ±0.80 was selected for the comparison since it was the largest positive and negative value obtained where all other flight conditions were the same.

Overall Force and Moment Coefficients

The overall force coefficients on the store and on the pylon were obtained by summation of the product of section load coefficients and the area represented by the measurement divided by the maximum cross-section frontal area of the store. The area represented by each measurement is that part of the total projected area in the plane normal to the measurement included between lines lying midway to the adjacent stations. In turn, moment coefficients were obtained about the store center of gravity $(x/l_m$ of 0.49) by summation of the product of the section forces and the arm extending to the centroid of the area represented by the measurement divided by the maximum cross-section frontal area of the store and the length of the store.

Variation of forces and moments with sideslip angle.- The variations with sideslip angle of the normal-force coefficients on the store, side-force coefficients on the store, and side-force coefficients on the pylon are given in figures 12, 13, and 14, respectively. The corresponding variations of the moment coefficients are given in similar order in figures 15, 16, and 17. In each figure curves are presented for three Mach numbers and for several values of airplane lift coefficient representing the range covered in these tests. The curves were obtained by the use of lines faired through the force- or moment-coefficient data plotted against lift coefficient for given values of sideslip angle. In a few cases where the data were considered inadequate for fairing, the curves given in figures 12 through 17 are not extended to the maximum values of sideslip angle reached in the tests.

Cross plots of the data given in figures 12 through 17 for a Mach number of 0.55 are presented in figure 18 in order to show the effect of angle of attack. The variations of the force and moment coefficients with sideslip angle are included in the figure for comparison with the angle-of-attack variations.

The variation of the normal-force coefficients with sideslip angle and lift coefficient (fig. 12) appears to change somewhat with Mach number. It is also indicated that the effect of sideslip angle, which is small at the low Mach number, increases substantially at the higher Mach numbers.

Side-force coefficients on the store vary with sideslip angle in about the same amount for any of the Mach numbers or lift coefficients presented in figure 13. The magnitudes of the coefficients, however, have a large variation with Mach number and lift coefficient.

The magnitudes of the side-force coefficients on the pylon (fig. 14) are smaller than those measured on the store. However, in view of the fact that the pylon side area is about 1/8 that of the store, side loads on larger pylons could become more critical than those on the store itself. For instance the values of the pylon loads given in figure 14 extrapolated to a pylon equal in side area to that of the store would result in loads 2 or 3 times as large as those on the store. It is also of interest to note from figure 14 that for most values of sideslip angle and lift coefficient the loads on the pylon act in a direction opposite to that of the side loads on the store. As in the case of side loads on the store, the side loads on the pylon vary with Mach number, but in a different manner than do those on the store. For example, at a sideslip angle of 0° the side load on the pylon increases positively (outboard) as the Mach number increases, whereas the side load on the store increases negatively (inboard) as the Mach number increases from 0.55 to 0.78 and then decreases negatively for the highest Mach number.

Pitching moments on the store (fig. 15) are relatively unaffected by sideslip angle. It can be seen that there is a large change in the magnitude of the pitching-moment coefficient at the highest Mach number. It is of interest to note that although the normal-force coefficient variation with lift coefficient is nonlinear, the pitching-moment coefficient variation is linear with lift coefficient. (See fig. 18.)

The same relationship is seen for the variation with lift coefficient of the side-force and yawing-moment coefficients on the store; that is, the variation is nonlinear for the side-force coefficients and linear for the yawing-moment coefficients. (See fig. 18.) It is indicated in figure 16 that neither the magnitude nor the variation with sideslip of the yawing-moment coefficient is appreciably affected by Mach number.

The pylon yawing-moment coefficients shown in figure 17 are small compared to those for the store. It should be noted that the scale for the pylon moment coefficients is smaller by a factor of 5 than that for the store moment coefficients. Here again Mach number has little effect on the yawing-moment characteristics.

The comparison given in figure 18 shows that the effects of side-slip angle and angle of attack on the side-force and yawing-moment coefficients on the store and pylon are of the same order of magnitude.

Comparison of flight test data with wind-tunnel data.- Some of the results of the present flight investigation can be compared with those obtained from wind-tunnel tests with a similar type external store installation consisting of a model tank of fineness ratio 6 mounted on a strut under a 40° sweptback wing. The test results, which were obtained at low speed and are for a tank without fins, are reported in reference 2. The strut chord is 1/4 the length of the tank. Of the various configurations tested, those which positioned the tank farthest back along the wing chord, with the tank axis 1.27 D_{MAX} below the mean chord of the

wing and at $\dfrac{y}{b/2}$ of 0.61 (configuration numbers "3" and "7"), most closely resembled that of the flight tests. With regard to the side loads on the store, values of about 0.07 for the overall side-force coefficient per degree of sideslip angle were measured for the model as compared to about 0.06 for the configurations of the flight tests. The change of the yawing-moment coefficients about the tank model center of gravity $(x/l_m$ of 0.46) per degree of sideslip-angle varies from about 0.013 to 0.018 depending upon whether or not the strut leading edge is flush with the wing leading edge. A value of about 0.018 was obtained during the flight tests. Although the trend is similar for both the normal-force and pitching-moment variation with sideslip angle for the two sets of data, the data are not directly comparable because of different vertical locations of the store, different wing aspect and taper ratios, and the fact that there were no fins on the model.

Variation of forces and moments with rolling velocity.- Variation with rolling velocity of the normal- and side-force coefficients on the store and of the side-force coefficients on the pylon along with the variations of the respective pitching- and yawing-moment coefficients are presented in figure 19 for two Mach numbers. The results are given as the incremental values of aerodynamic forces and moments that are imposed on the store due to the effect of rolling velocity. Test values at the Mach number of 0.55 were obtained at values of sideslip angle ranging from -1° to 3° and at lift coefficients from -0.02 to 0.58, while at the Mach number of 0.78 the values of sideslip angle varied between ±1° and lift coefficient between 0.15 and 0.34.

Examination of the test data indicates that, except for the normal force, there is little or no change in the forces and moments on the right store or pylon due to negative rolling velocity.

It has been indicated by the load distributions (see fig. 10) that the effect of positive rolling velocity on the side forces and yawing moments on the store and pylon can be calculated if the variation with

airplane lift coefficient is known. Assuming that the rolling velocity
effect is basically that which is produced by the incremental lift coef-
ficient induced at the store, calculations were made by use of the
expression

$$\Delta\alpha = y\,\frac{p}{V} \tag{1}$$

where V is true airspeed in feet per second. The incremental lift coef-
ficient corresponding to this change in angle of attack was then deter-
mined from the lift-curve slope. Finally, the incremental values of the
force and moment coefficients were obtained directly from the data plots
of their variation with lift coefficient. This variation remains about
the same for any sideslip angle, thus the variation for zero sideslip
angle was employed in the calculations. For a given Mach number the
true airspeed used in equation (1) varies as the altitude; therefore,
the calculations were made for the altitude at which rolls were made
during the tests (30,000 feet). The calculations, which are for the
normal forces and pitching moments as well as the side forces and yawing
moments, are presented for two Mach numbers in figure 19 for comparison
with the test values.

It can be seen that the calculated values in figure 19 compare
favorably with the test values for the side forces and yawing moments
on the store and pylon. Some scatter in the test data can ordinarily
be expected because of the relatively small loads represented by the
coefficients; however, the excessive scatter shown for the store side-
force coefficients at the positive rolling velocities is, for the most
part, due to the nonlinearity of the side-force variation with lift coef-
ficient. The incremental test values shown near zero side-force coef-
ficient were measured at low lift coefficients where the change in store
side force with lift coefficient is small. (See fig. 13.) The calculated
curves for the store side force are for the high lift coefficient range
where the largest incremental loads were obtained.

The calculated curves for the normal-force coefficients are also
shown for the high lift coefficient range. As can be seen the method
is inadequate for predicting the rolling velocity effect on the normal
forces. Other variables such as those previously mentioned in the dis-
cussion of the load distributions would have to be taken into considera-
tion where calculations are to be made. Since the calculated and test
values do not agree for the normal forces, it is probably coincidental
that the calculated and test values are practically the same for the
pitching moments.

Inertia Effects on Store Normal and Side Loads

Thus far only the aerodynamic effects have been discussed, however, there may be large inertia effects due to the location of the store. In order to illustrate the relative effect of inertia, a comparison of the aerodynamic and calculated inertia loads due to rolling velocity is presented in figure 20. In addition, the inertia effects of rolling acceleration and of the linear accelerations of the airplane are shown. The inertia calculations are for a store weight of 1,450 pounds, which is what the store would weigh with its rated amount of fuel, and the incremental aerodynamic loads are for sea-level conditions.

In the inertia calculations the centrifugal loads on the store caused by the rolling velocity are given by

$$N_S \text{ or } Y_S = mp^2d \tag{2}$$

where d is the vertical or transverse distance in feet, respectively, of the store from the airplane center of gravity and m is the mass. The loads on the store due to the tangential forces caused by the rolling acceleration are given by

$$N_S \text{ or } Y_S = m\dot{p}d \tag{3}$$

where d is the transverse or vertical distance, respectively, of the store from the airplane center of gravity. Inertia loads caused by the linear accelerations are simply the weight times the airplane normal load factor. The values of the rolling acceleration and of the normal and transverse load factor used in the calculations were arbitrarily selected and are in general fairly representative of the most severe motions that would be experienced. The inertia effects due to yawing and pitching velocities and accelerations are negligible and therefore are omitted in figure 20.

It is apparent for this installation with the weight as quoted that the inertia loads in rolling type maneuvers are the more significant. For example, in figure 20(b) for a rolling velocity of about +1.5 radians per second the inertia side load is about 800 pounds as compared to about 200 pounds for the incremental aerodynamic side load. If, along with the rolling velocity of +1.5 radians per second, the rolling acceleration of +3.0 radians per second per second and the transverse load factor of 0.5 to the left are included, the combined value for the inertia side loads is about 2,000 pounds.

From the data presented in figure 13 (for a Mach number of 0.78) the maximum aerodynamic store side load $\left(C_{Y_S} = -0.6\right)$ at sea level is approximately -2,500 pounds. Comparison of this value with the inertia loads given in figure 20(b) shows that the inertia loads (for the loaded store) and aerodynamic loads would be of about equal importance when designing the store for all types of maneuvers at any flight condition.

CONCLUDING REMARKS

The results indicate that for this installation the pitching moments are relatively unaffected by sideslip angle. It is also indicated that the effect of sideslip angle on the normal forces is small at low Mach numbers, but increases considerably at the higher Mach numbers. With respect to the side forces and yawing moments on the store and pylon, the effect of sideslip angle is of the same order of magnitude as that of the angle of attack or lift coefficient. In general, the effects of Mach number on the forces and moments on the store and pylon appear to be of greatest importance in the region of the maximum obtainable Mach number due to a type of high-speed buffeting.

With regard to angular motions of the airplane it is indicated that there is little or no effect of yawing or pitching velocity on the external store aerodynamic loads. The aerodynamic effect of rolling velocity on the side forces and yawing moments on the store and pylon, in which the direction of the wing from which the store is suspended is downward, is primarily attributed to the increased lift coefficient due to the induced angle of attack at the store. For rolling velocity in which the direction of the wing is upward the aerodynamic effect on the normal and side loads is negligible.

It is shown that during rolling type maneuvers with a fully loaded store the inertia effects on the store normal and side loads would generally be greater than the aerodynamic effects.

Langley Aeronautical Laboratory,
        National Advisory Committee for Aeronautics,
            Langley Field, Va., July 15, 1955.

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      on a 40° Swept Back Wing. Tech. Note No. Aero. 2095, British R.A.E.,
      Mar. 1951.

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      Pressure Distribution and Jettisoning of Strut Tanks on a 40° Swept
      Back Wing. Addendum: Further Pressure Plotting Tests. Tech. Note
      No. Aero. 2095b, British R.A.E., June 1952.

3. O'Bryan, Thomas C.: Flight Measurement of Aerodynamic Loads and
      Moments on an External Store Mounted Under the Wing of a Swept-Wing
      Fighter-Type Airplane. NACA RM L53G22, 1953.

4. Thompson, Jim Rogers, O'Bryan, Thomas C., and Kurbjun, Max C.: A
      Limited Analysis of Buffeting Experienced in Flight by a North
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      NACA RM L54J22, 1955.

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      Flight Calibration of Angle-of-attack and Sideslip Detectors on the
      Fuselage of a 35° Swept-Wing Fighter Airplane. NACA RM A52A04, 1952.

TABLE I

PERTINENT DIMENSIONS AND PHYSICAL CHARACTERISTICS OF

TEST AIRPLANE AND EXTERNAL-STORE INSTALLATION

Airplane

Total wing area, sq ft 287.9
Wing span, ft 37.1

External Store and Pylon

Dimensions measured normal to store center line and normal to pylon center line, in.

Store			Pylon		
l_s	$w_s/2$	$h_s/2$	l_p	$w_p/2$	$h_p/2$
3.6	6.0	4.0	3.4	1.5	3.7
14.6	10.8	8.8	13.4	1.0	3.0
29.2	14.1	12.4	25.2	1.0	2.5
51.1	15.8	13.5	40.2	1.0	2.5
73.0	15.6	13.4	53.6	1.0	3.0
94.9	13.7	11.5	63.6	0.2	4.0
116.8	10.1	8.2			
131.4	7.0	5.0			
142.4	3.9	2.0			

Total projected area of store and pylon, sq ft
  Lift area (store and fins) 27.7
  Side area of store 20.4
  Side area of pylon 2.6

Maximum cross-section frontal area of store, sq ft 4.7
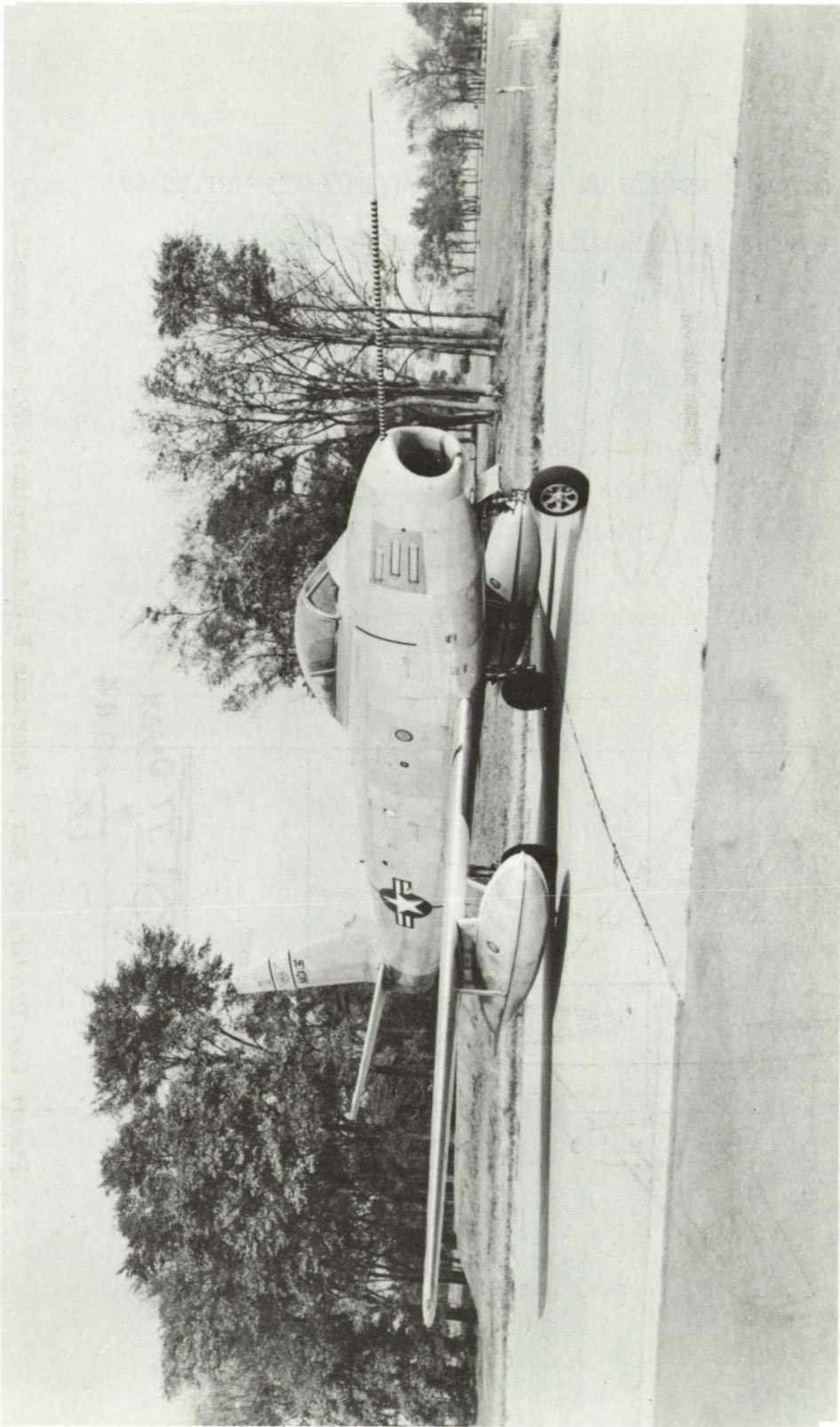
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Figure 1.- Photograph of North American F-86A airplane with 245-gallon external fuel tanks installed.

PYLON
t/c = 0.05

SWAY BRACES

1.77 D_{MAX}

$\dfrac{y}{b/2} = 0.44$
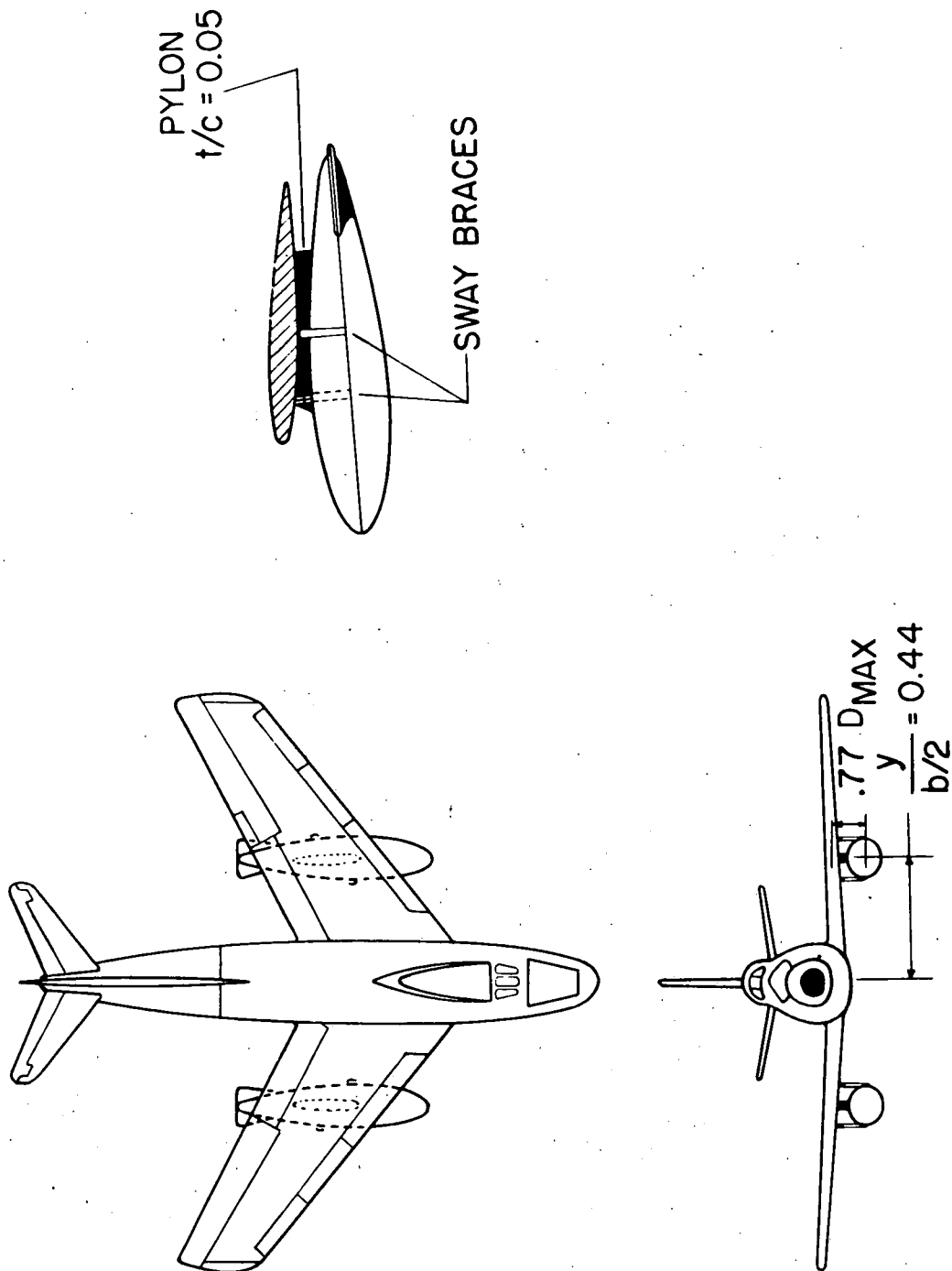
Figure 2.- Drawing of North American F-86A airplane showing details of external fuel-tank installation.
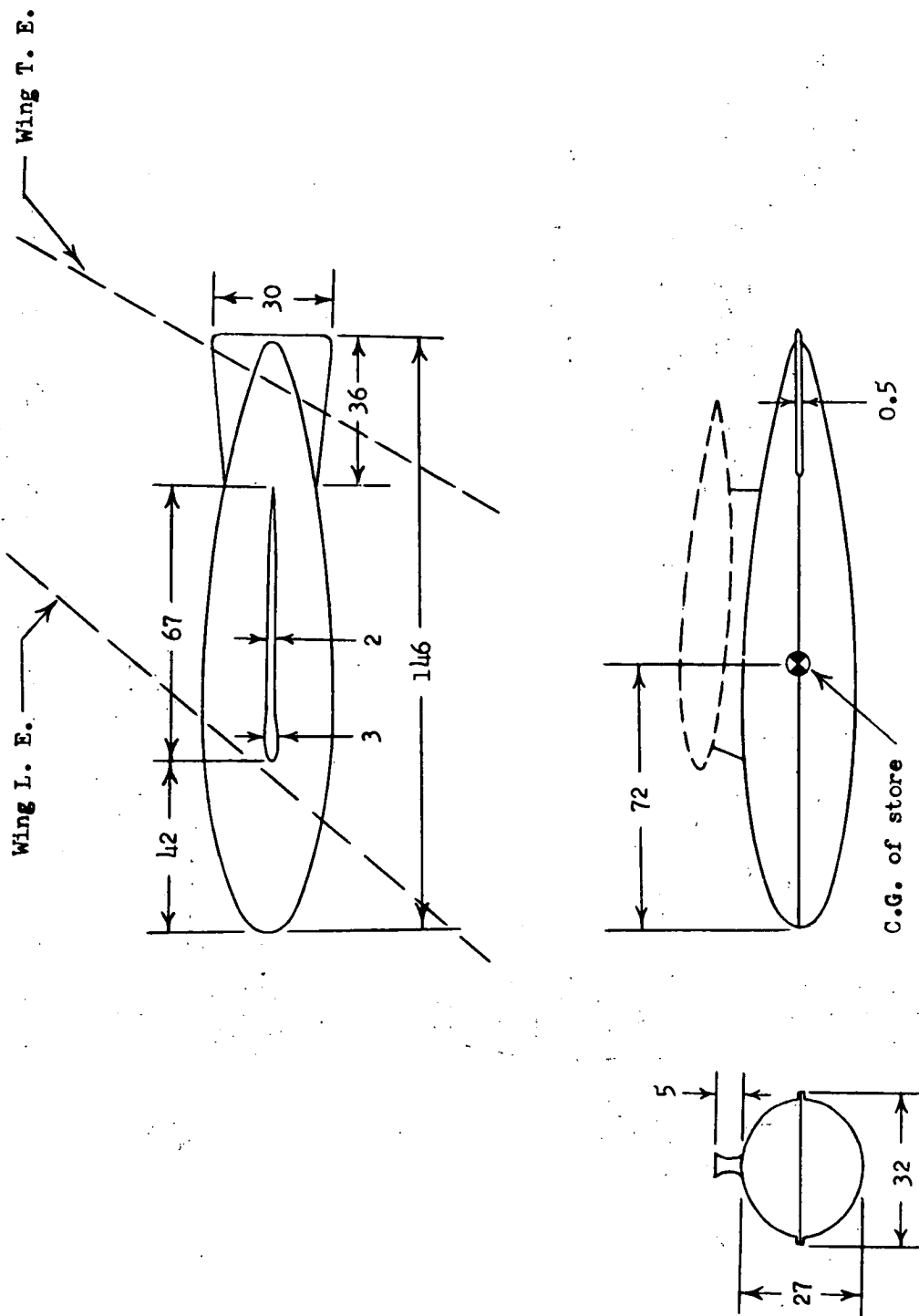
Figure 3.- Dimensioned drawing of external store. All dimensions are in inches.
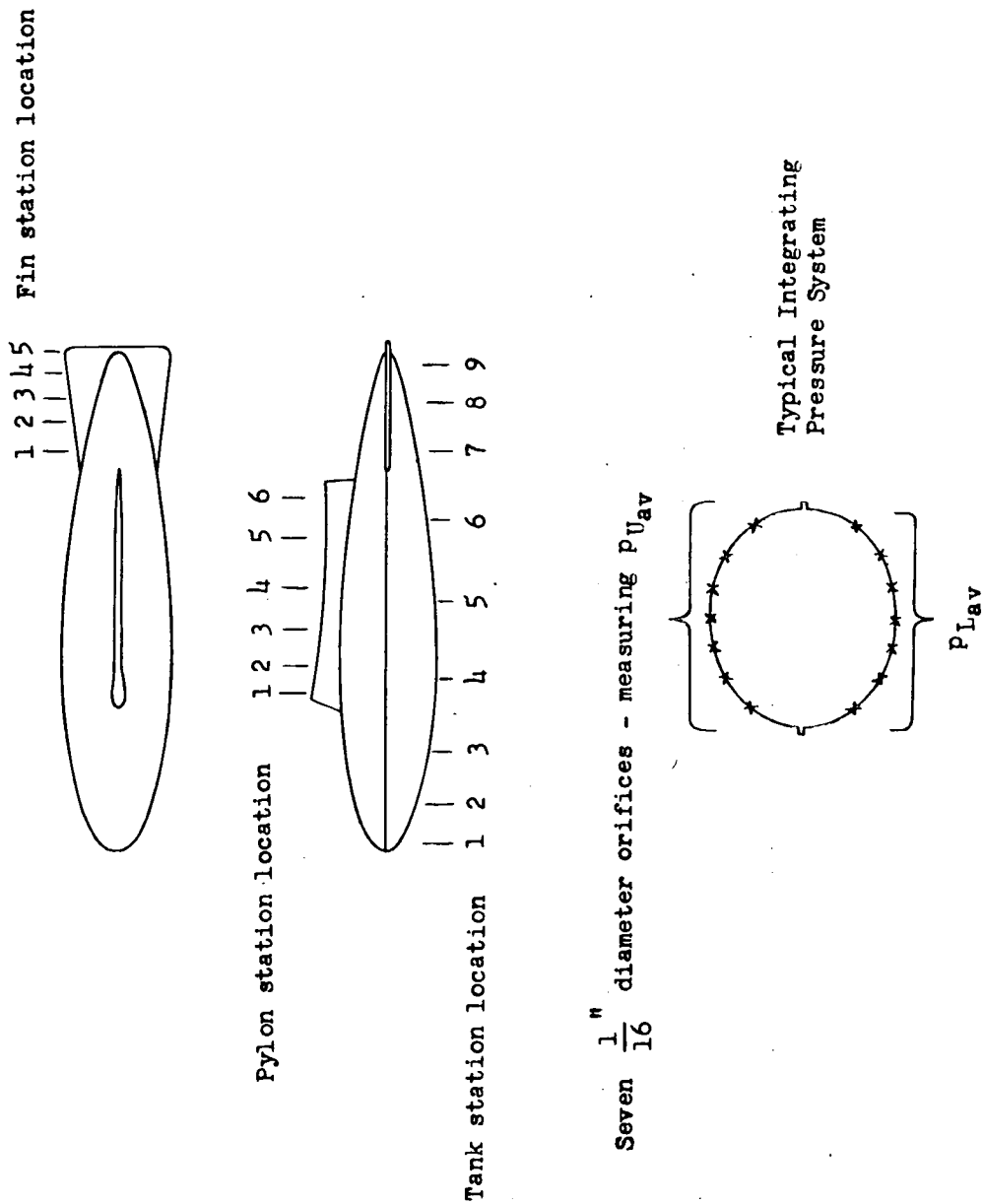
Figure 4.- Drawing of 245-gallon external fuel tank showing location of measuring stations and details of one typical measuring station.
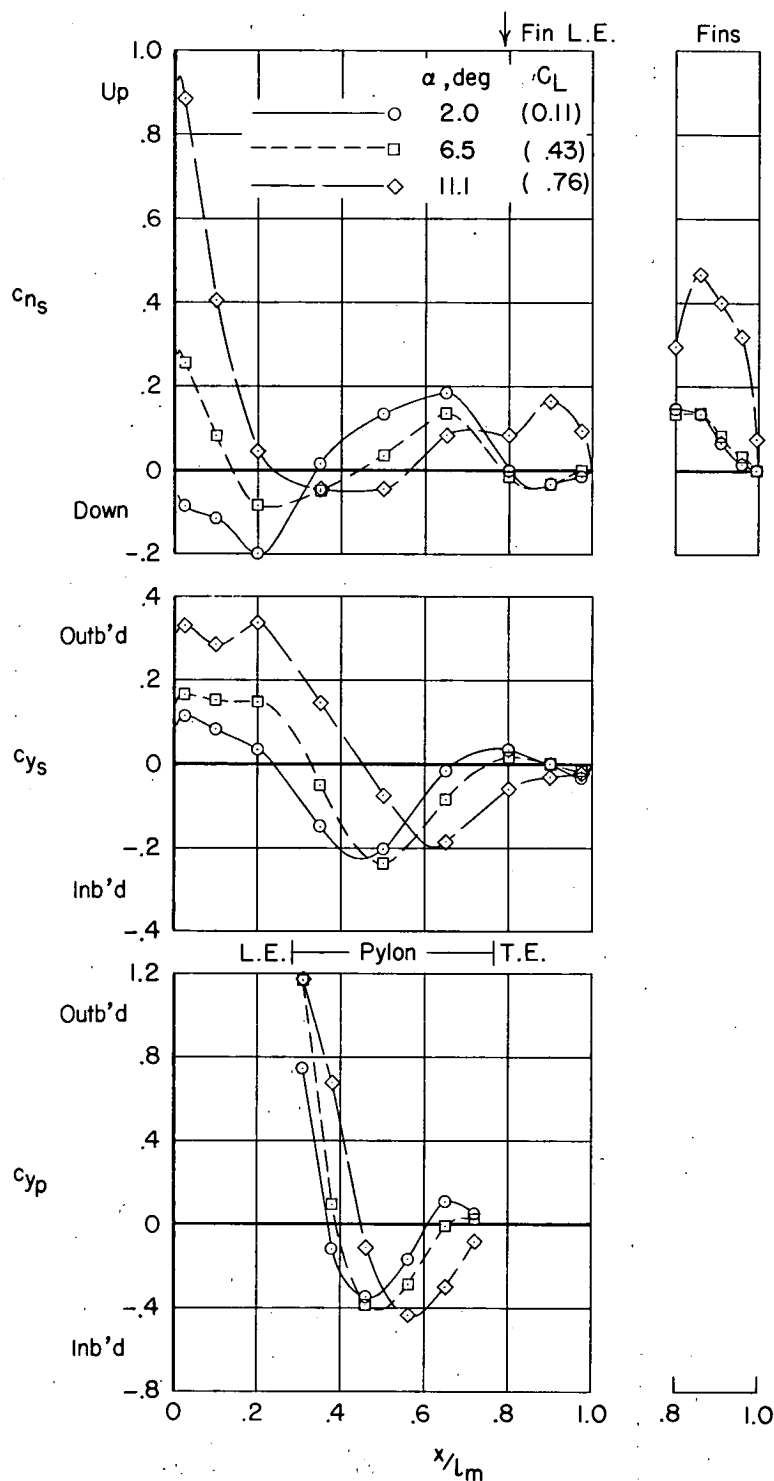
Figure 5.- Typical section normal- and side-load coefficient distributions
    on store, fins, or pylon at a Mach number of 0.55 for three airplane
   angles of attack. $\beta = 0°$.
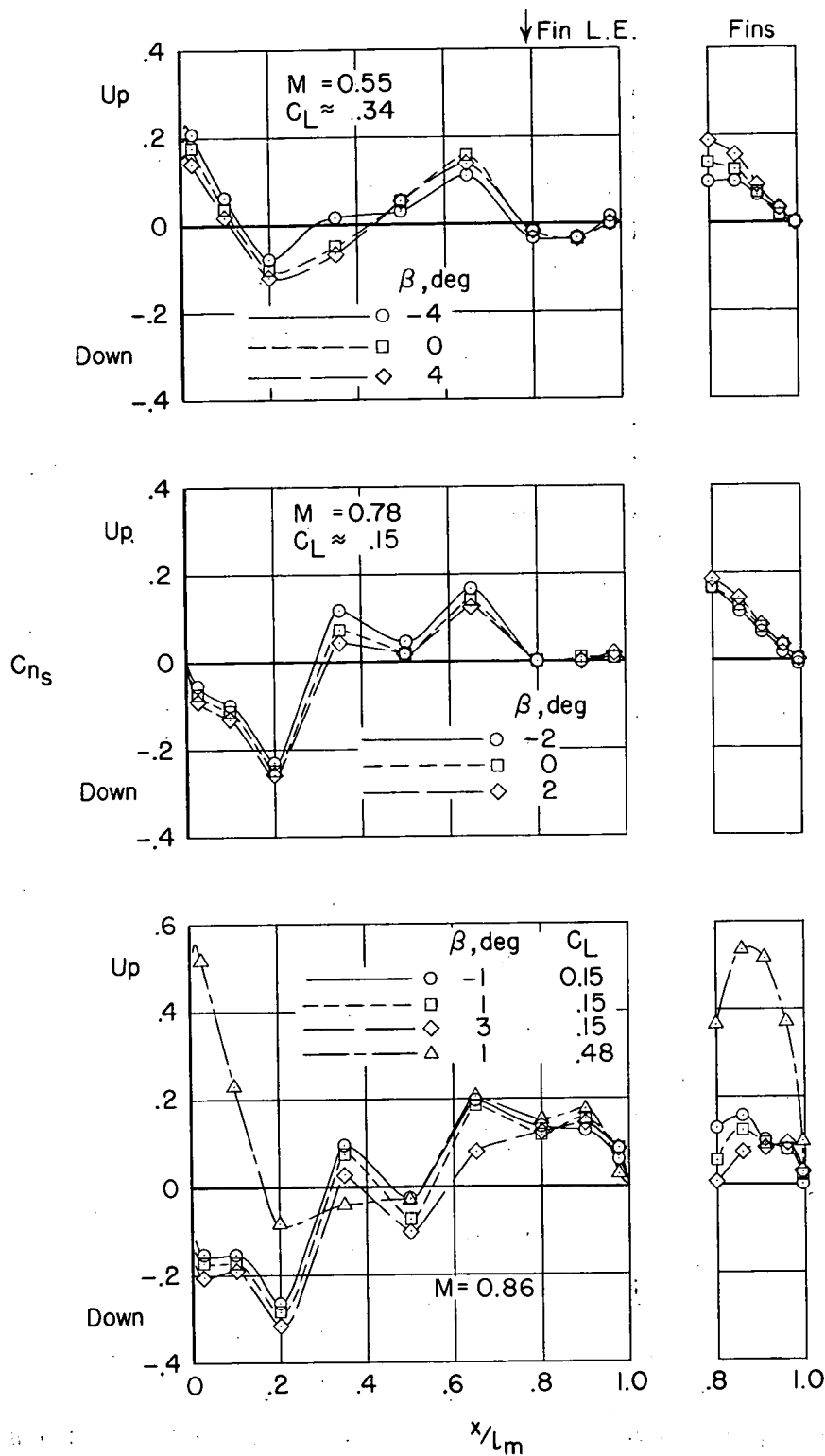
Figure 6.- Typical section normal-load coefficient distributions on store and fins at three Mach numbers for various airplane sideslip angles.
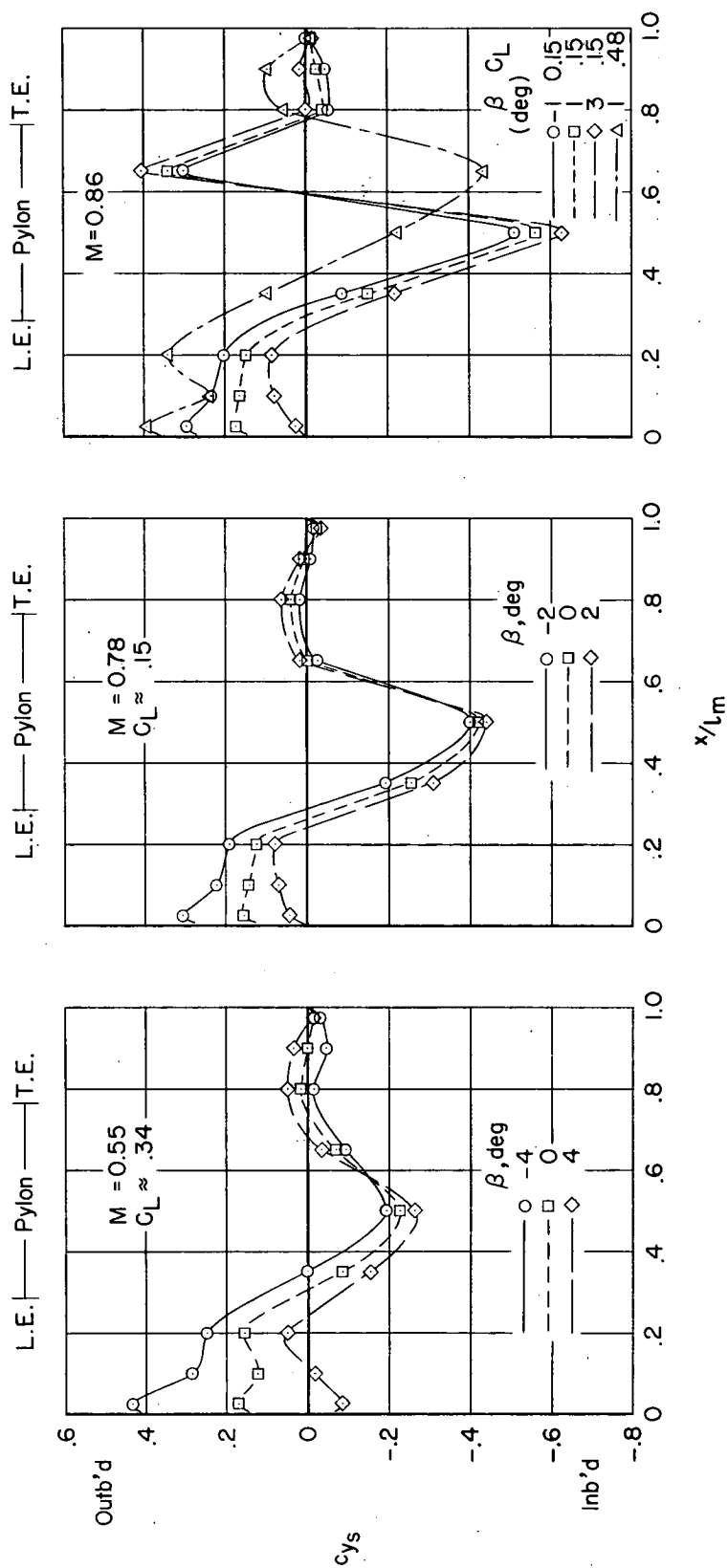
Figure 7.- Typical section side-load coefficient distributions on store
at three Mach numbers for various airplane sideslip angles.
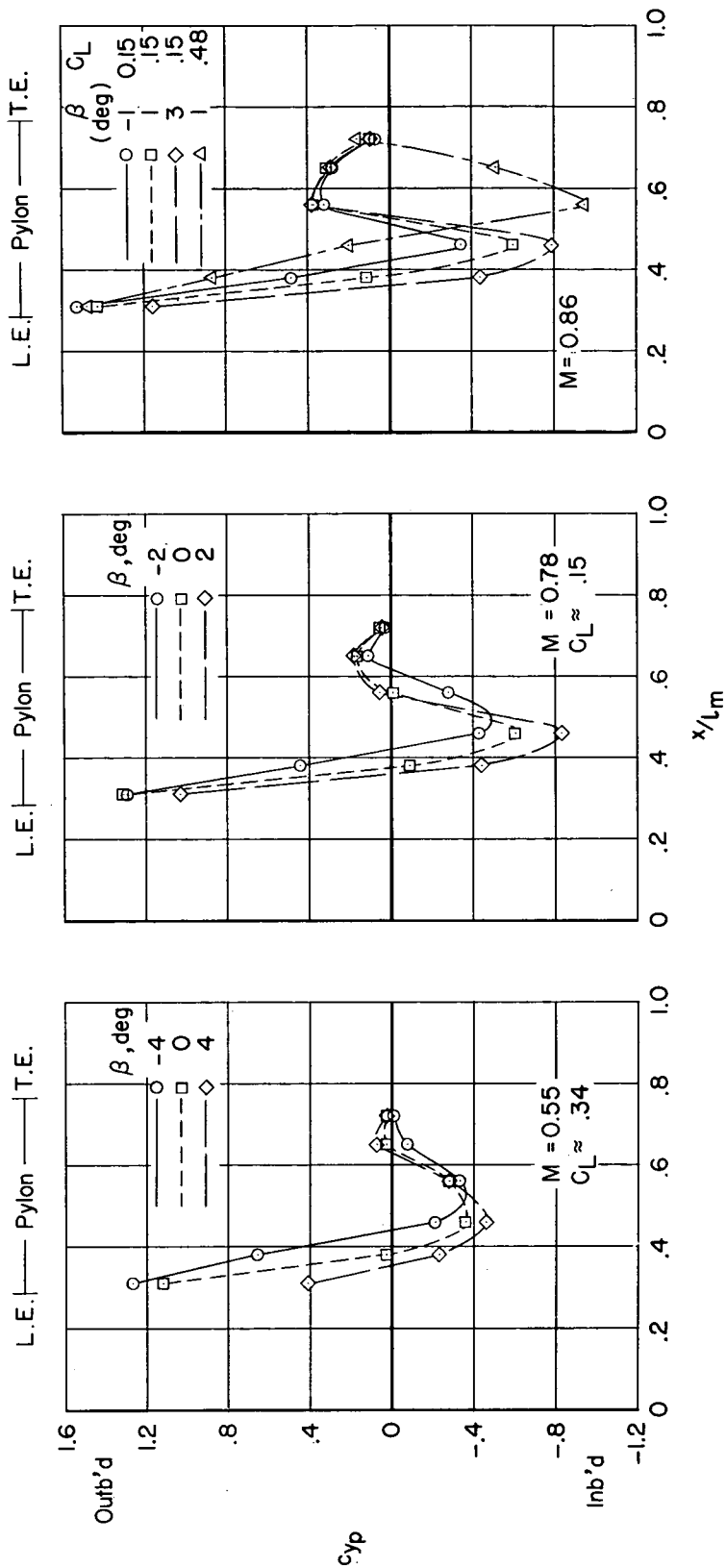
Figure 8.- Typical section side-load coefficient distributions on pylon at three Mach numbers for various airplane sideslip angles.
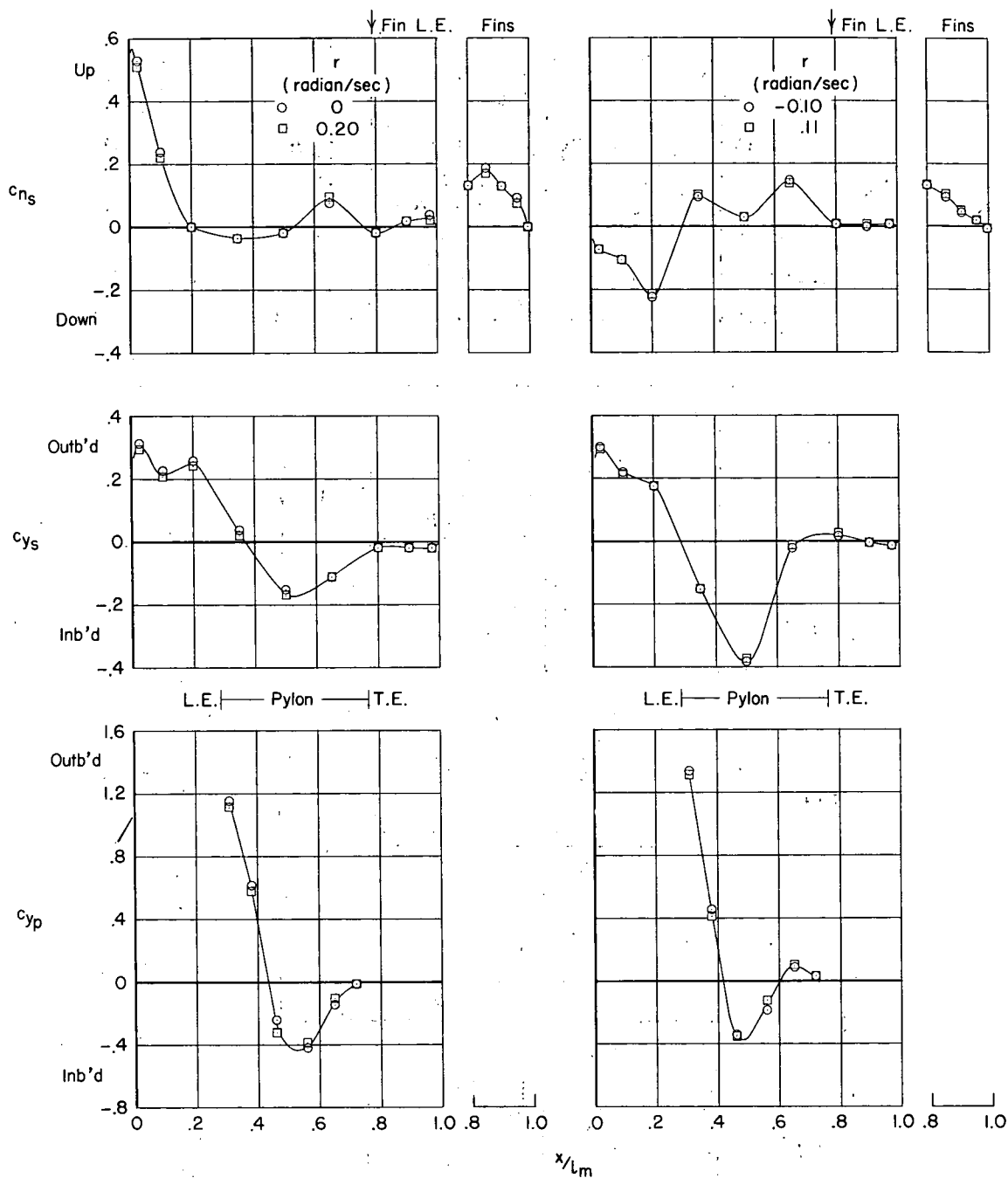
(a) M = 0.55.

$\left(C_L \approx 0.60, \quad \beta = -1^{\circ}. \right)$

(b) M = 0.83.

$\left(C_L \approx 0.12, \quad \beta = -2^{\circ}. \right)$

Figure 9.- Effect of airplane yawing velocity on typical section normal- and side-load coefficient distributions on right store, fins, or pylon for two Mach numbers.
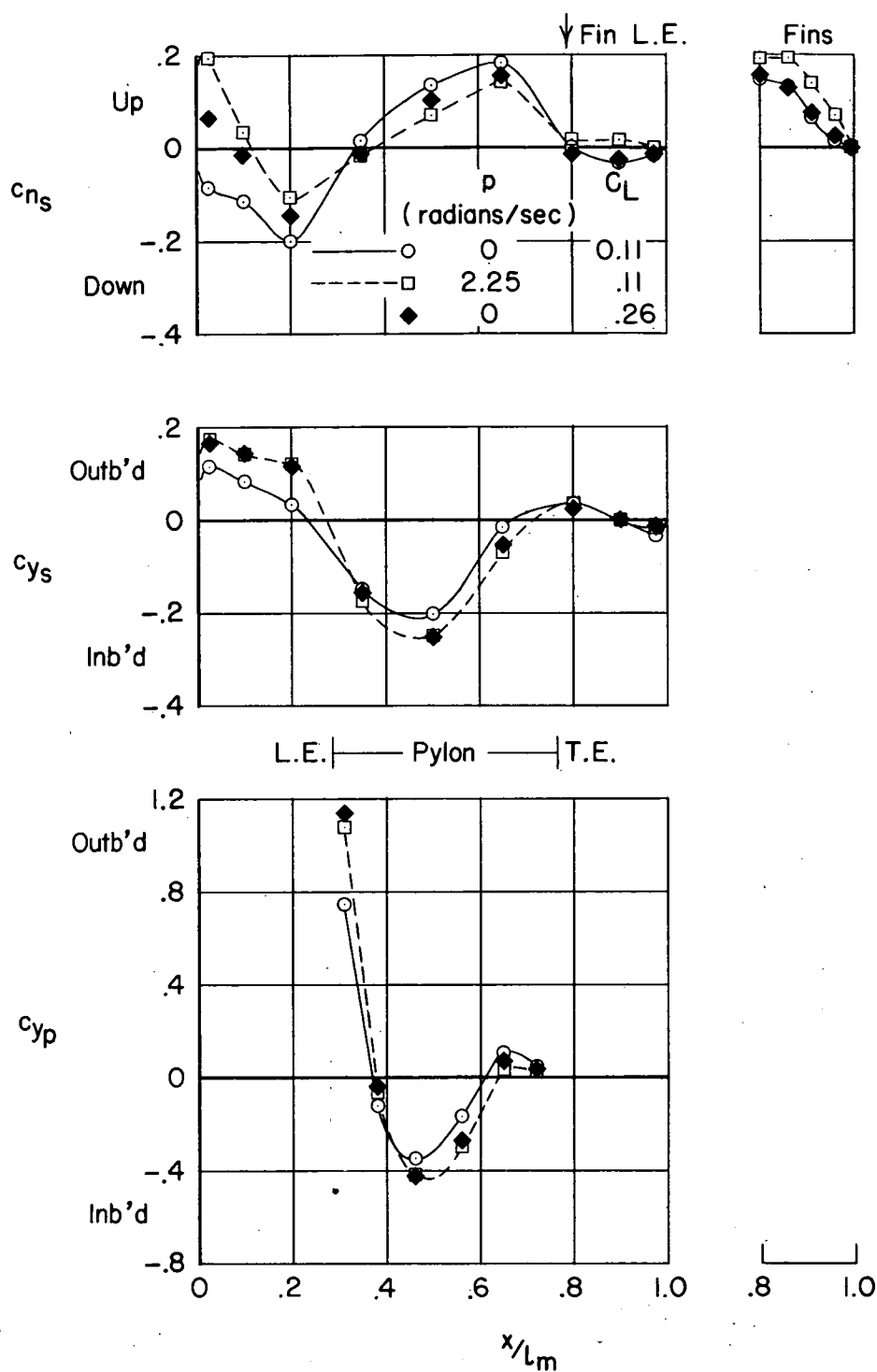
Figure 10.- Effect of positive airplane rolling velocity and airplane lift coefficient on typical section normal- and side-load coefficient distributions on right store, fins, or pylon at a Mach number of 0.55. β = 0°.
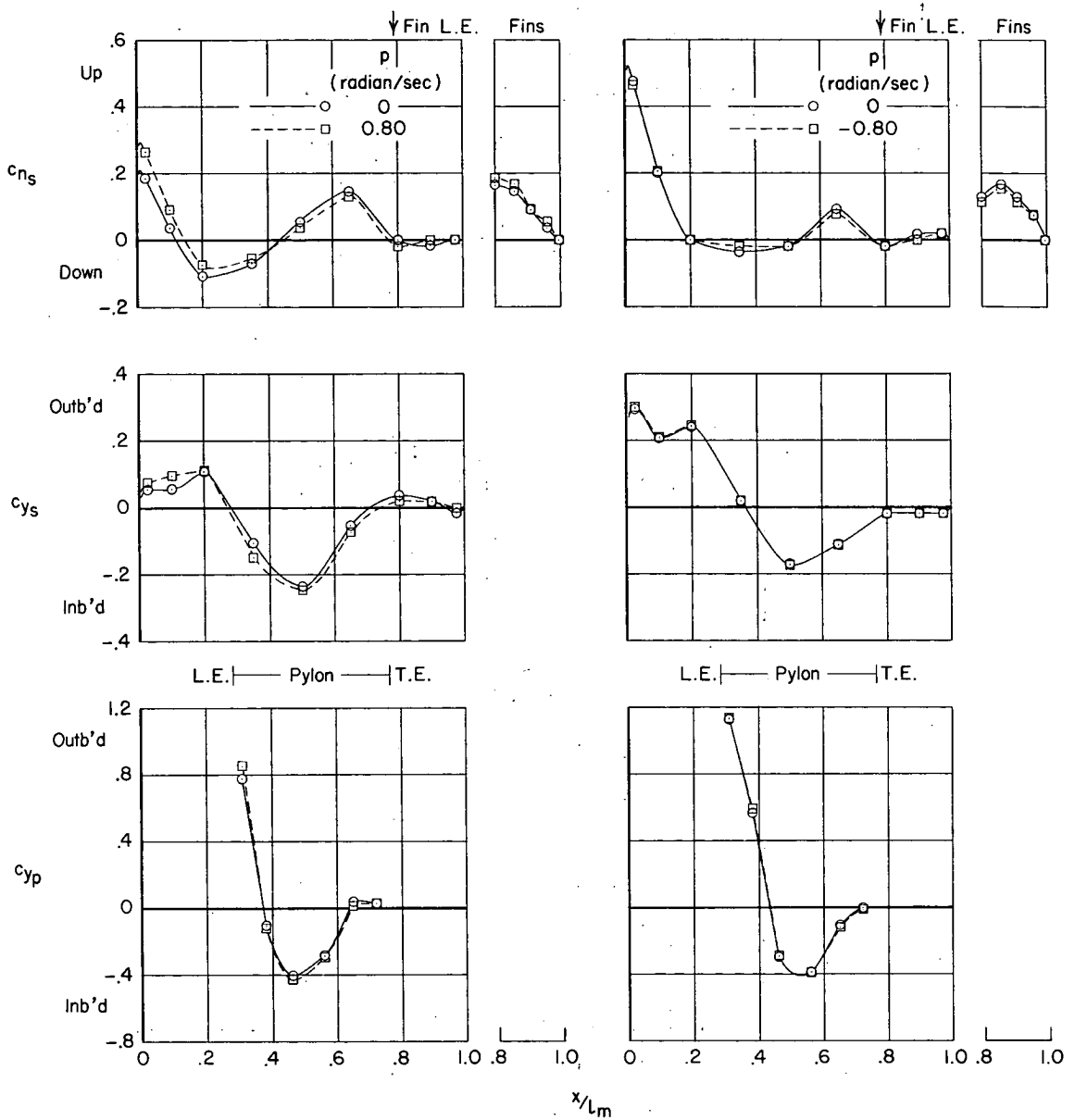
(a) Positive rolling velocity.
$\left(C_{L} \approx 0.37, \quad \beta = 2^{\circ}. \right)$

(b) Negative rolling velocity.
$\left(C_{L} \approx 0.57, \quad \beta = -1^{\circ}. \right)$

Figure 11.- Comparison of the effect of positive and negative airplane
rolling velocity on typical section normal- and side-load coefficient
distributions on right store, fins, or pylon at a Mach number of 0.55.
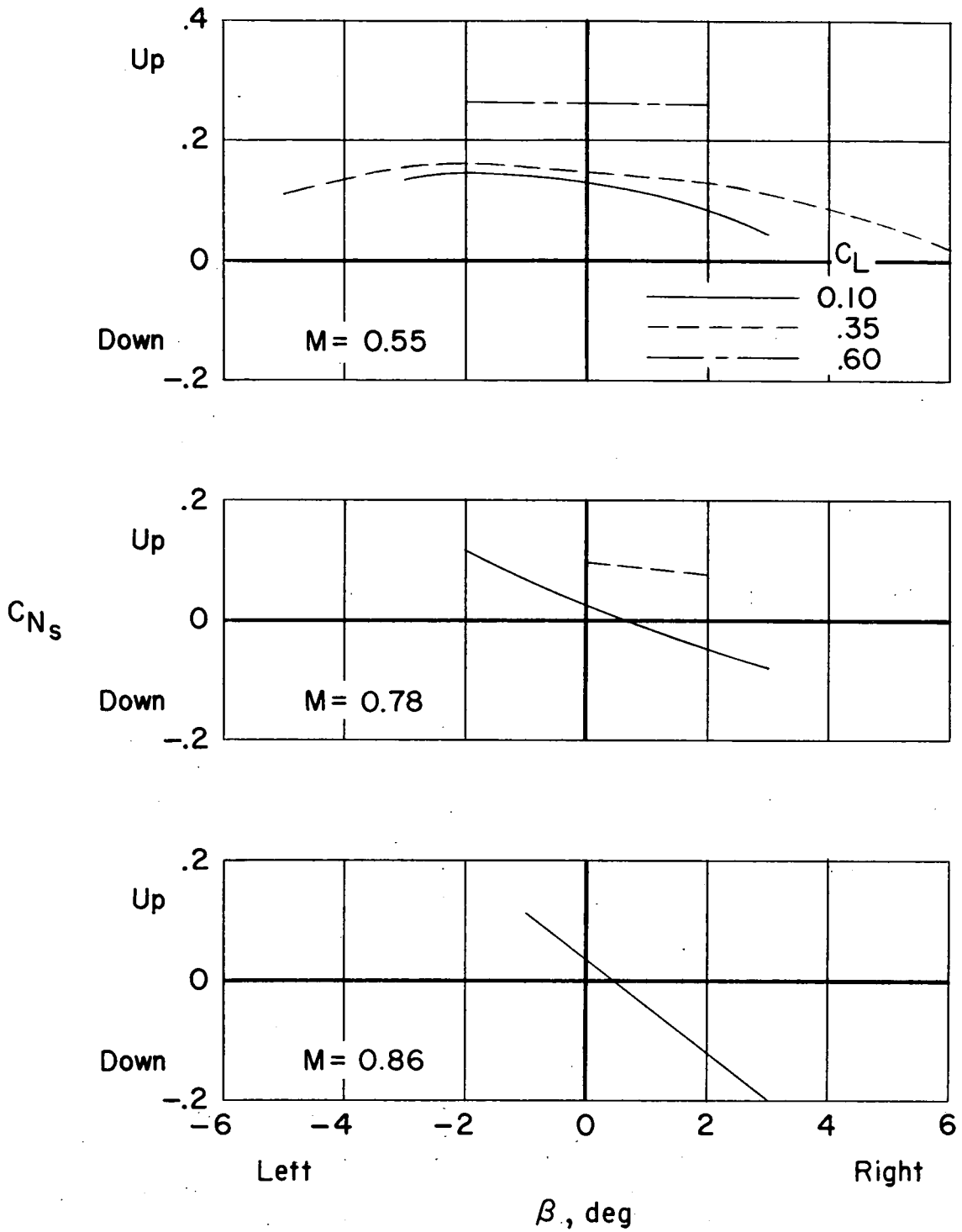
Figure 12.- Variation of overall normal-force coefficient on store and fins with sideslip angle for three Mach numbers at various airplane lift coefficients.
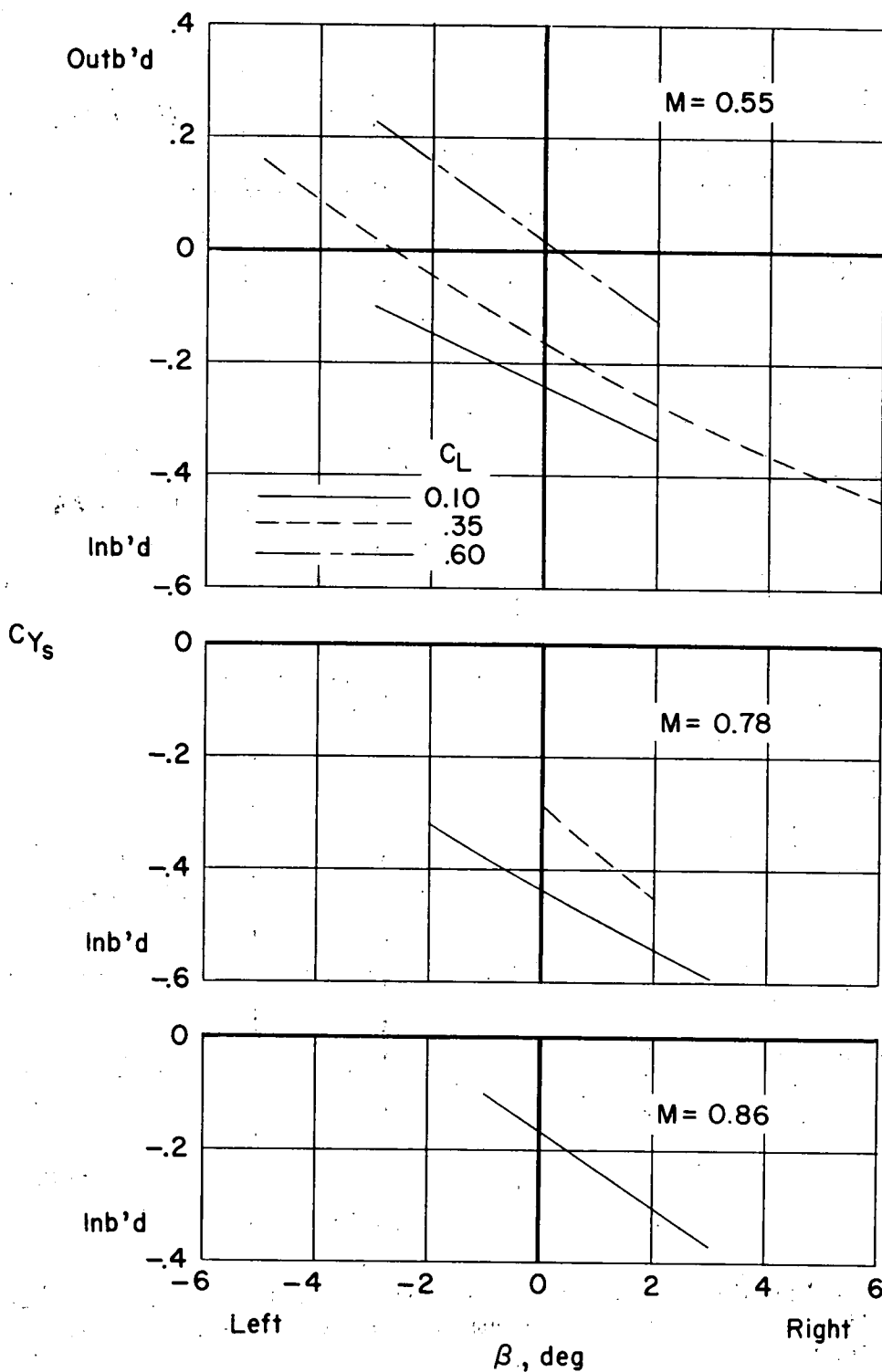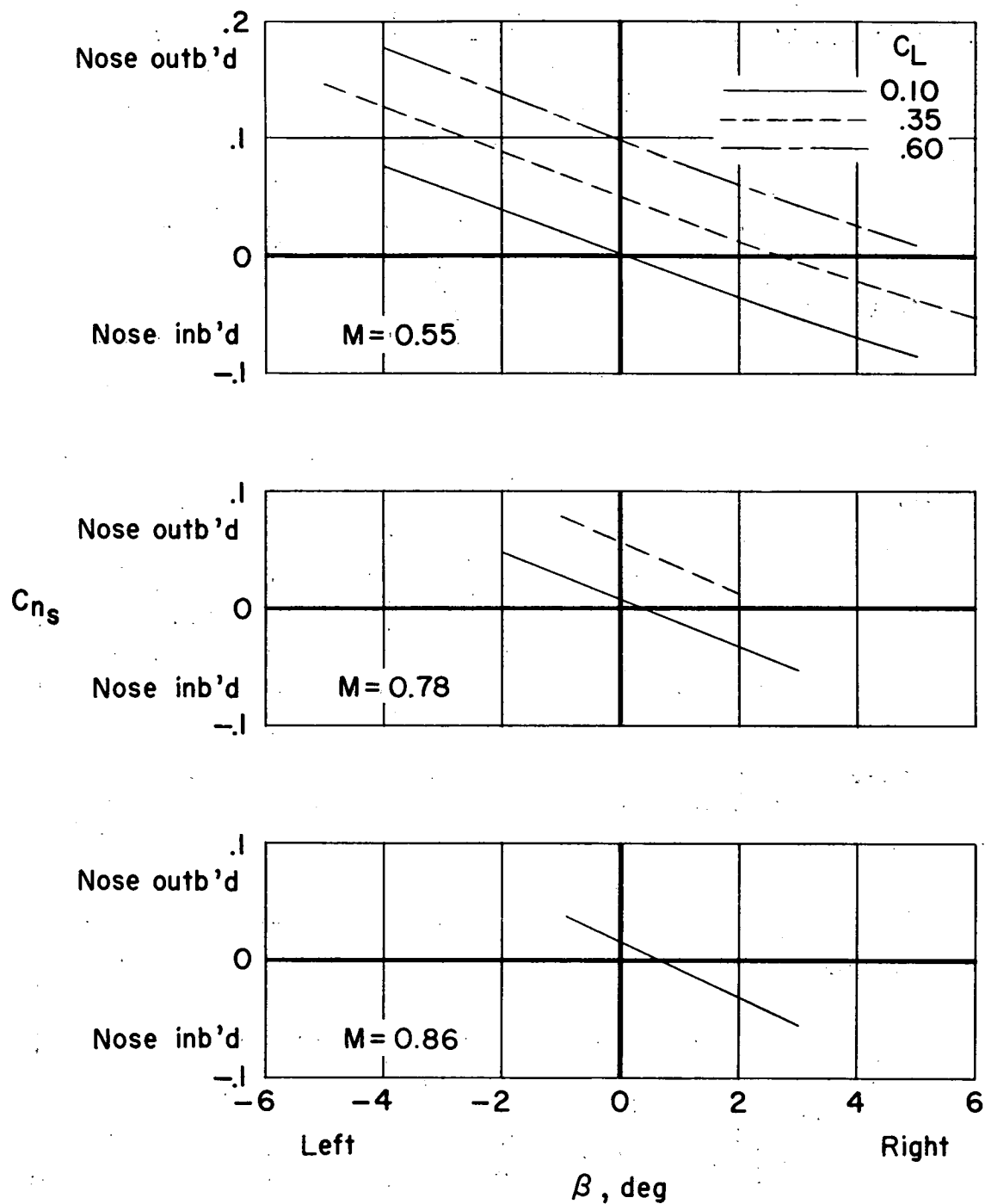
Figure 13.- Variation of overall side-force coefficient on store with sideslip angle for three Mach numbers at various airplane lift coefficients.
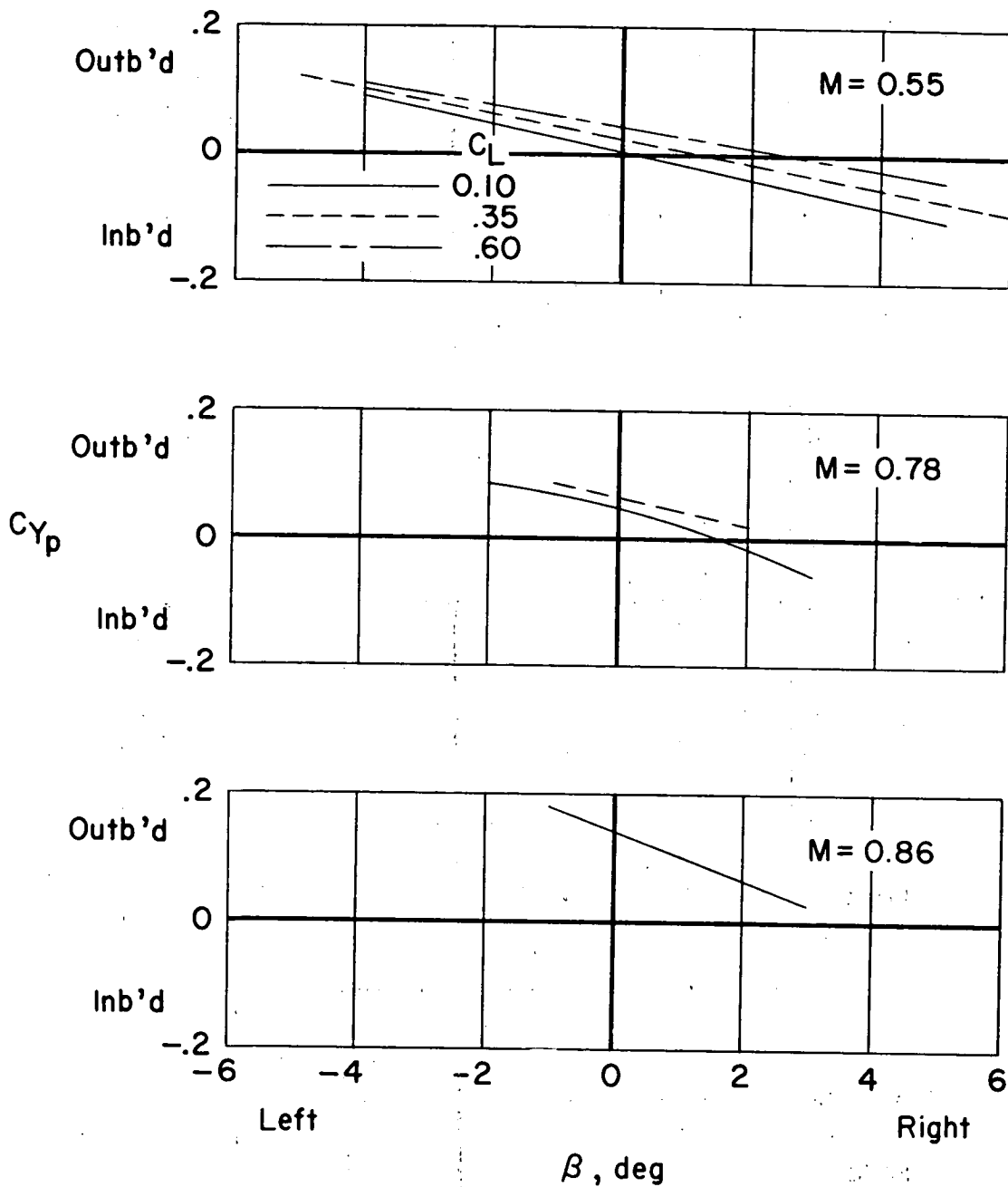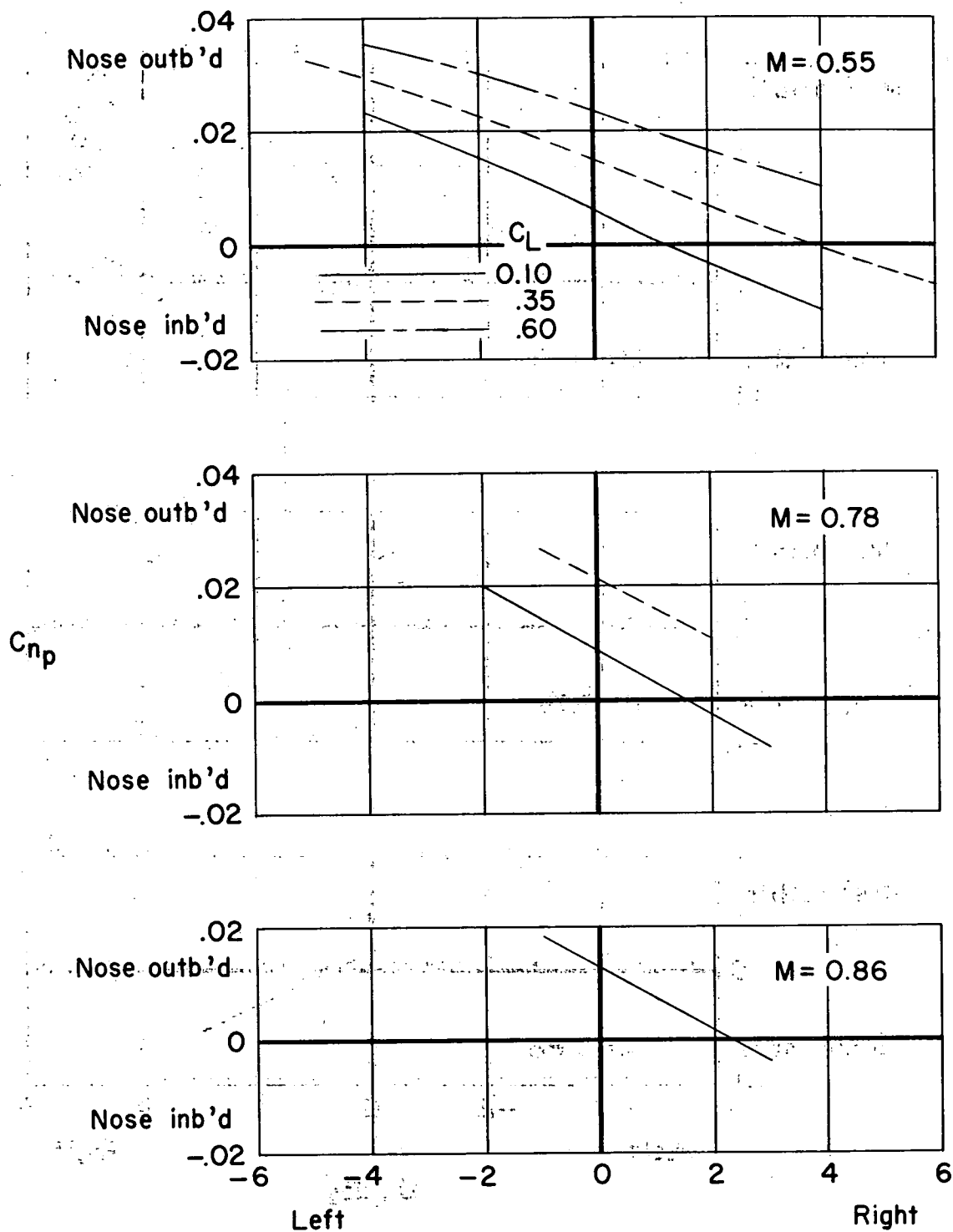
Figure 14.- Variation of overall side-force coefficient on pylon with sideslip angle for three Mach numbers at various airplane lift coefficients.
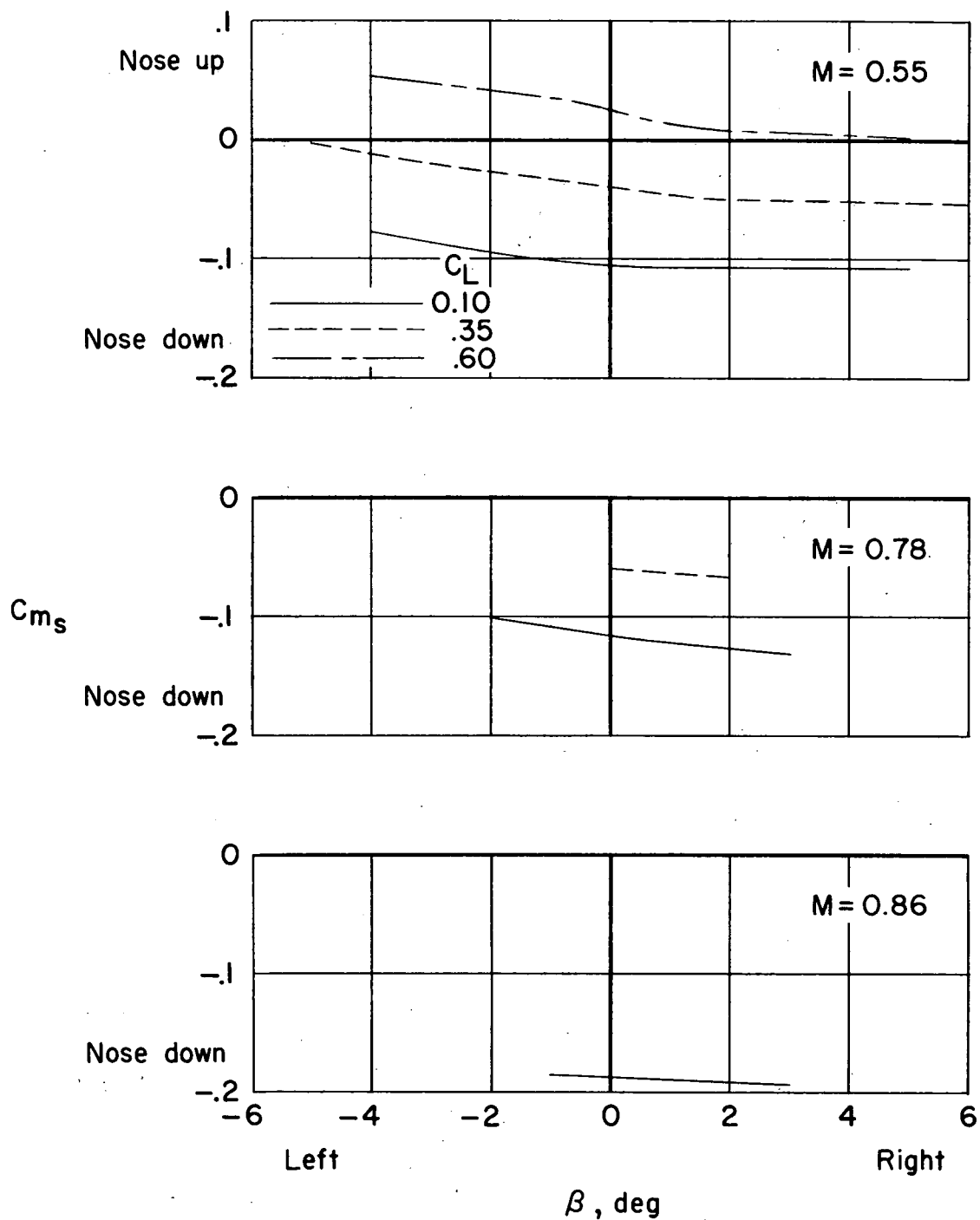
Figure 15.- Variation of pitching-moment coefficient on store and fins
    with sideslip angle for three Mach numbers at various airplane lift
    coefficients.

Figure 16.- Variation of yawing-moment coefficient on store with sideslip angle for three Mach numbers at various airplane lift coefficients.

Figure 17.- Variation of yawing-moment coefficient on pylon with sideslip
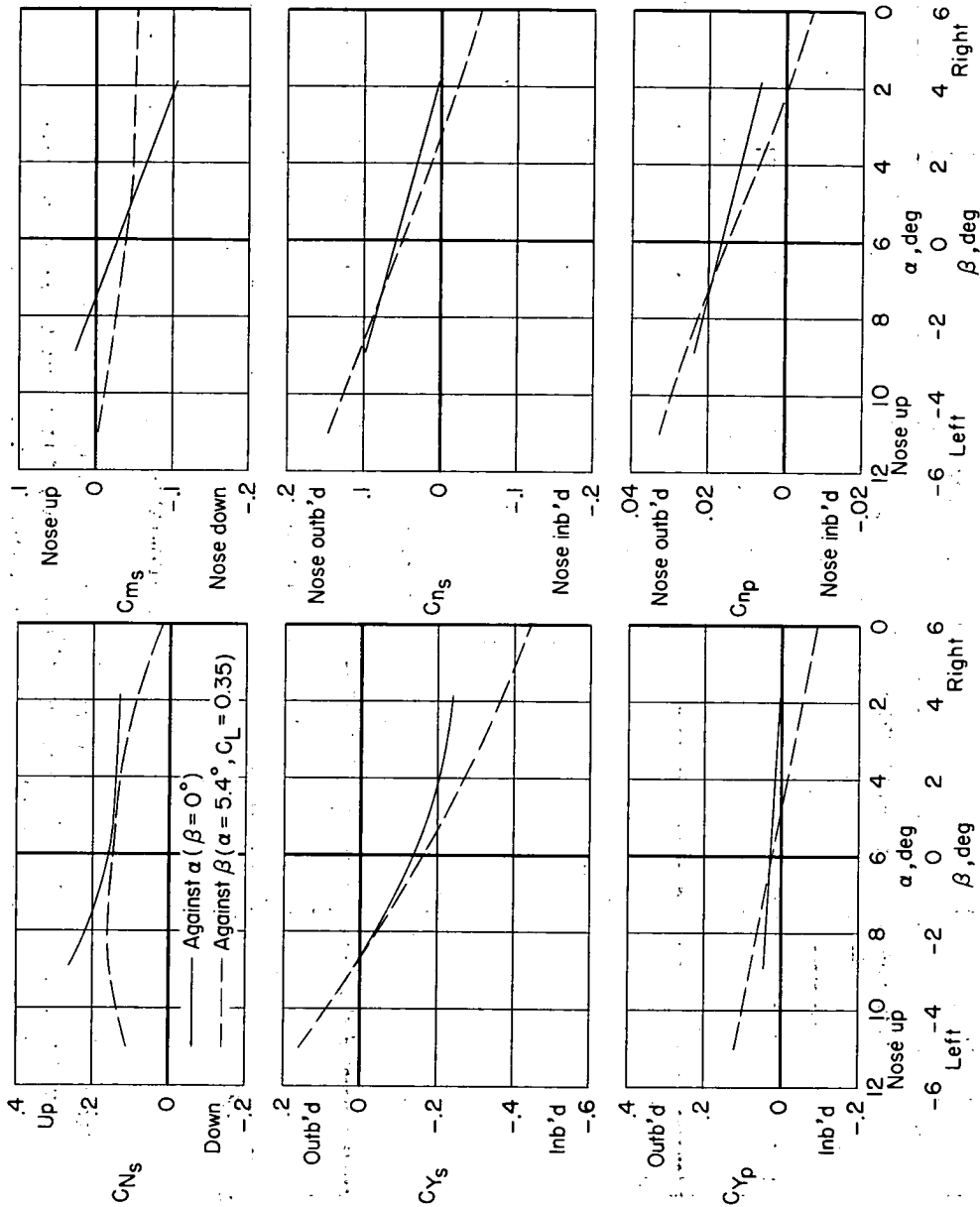angle for three Mach numbers at various airplane lift coefficients.

Figure 18.- Comparison of the effect of airplane angle of attack and sideslip angle on the overall force and moment coefficients on store, fins, and pylon at a Mach number of 0.55.
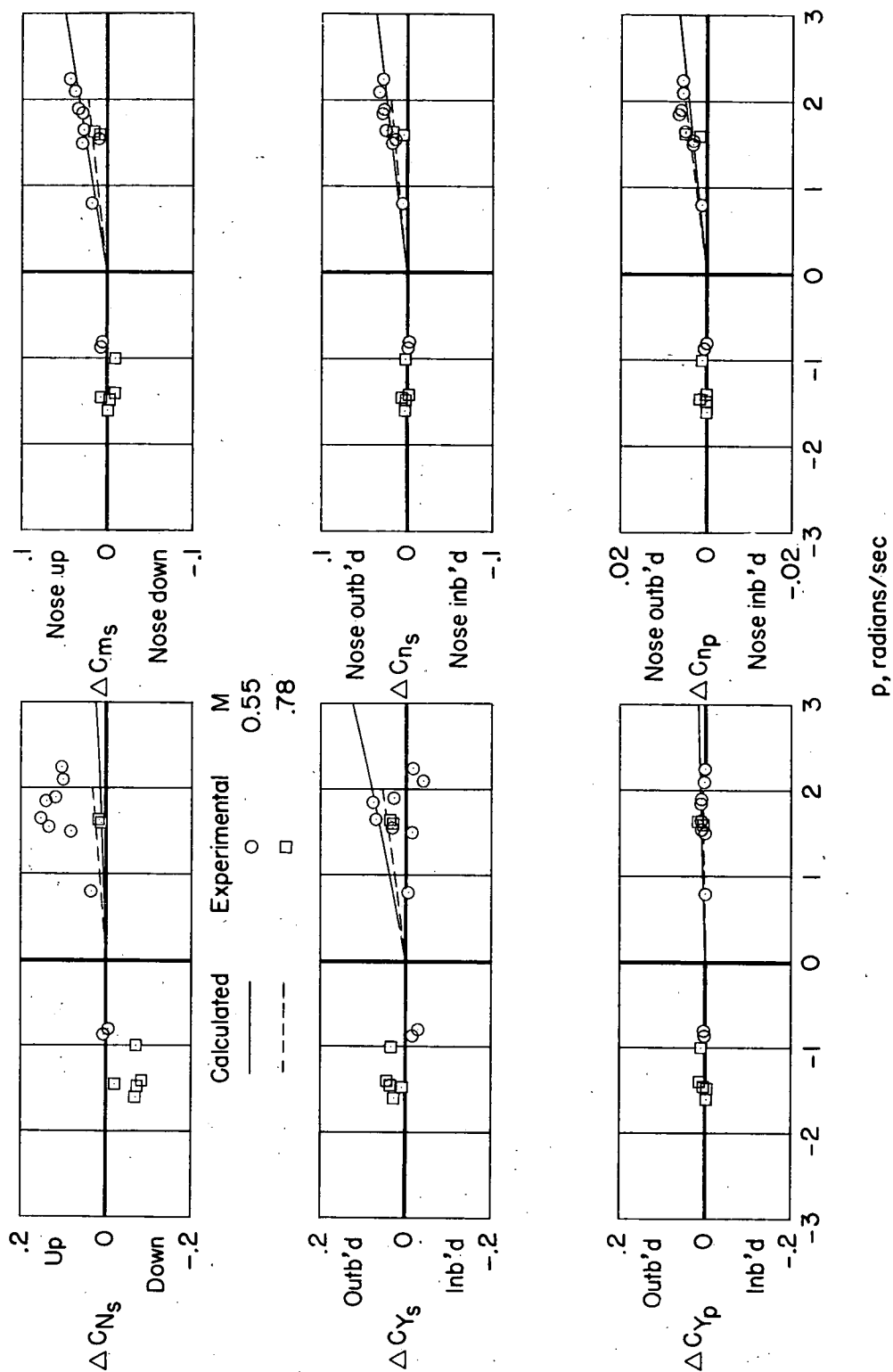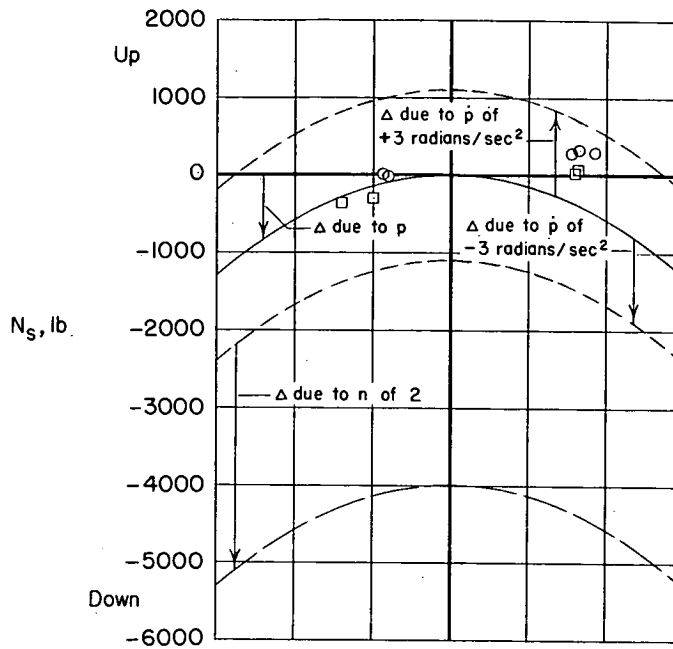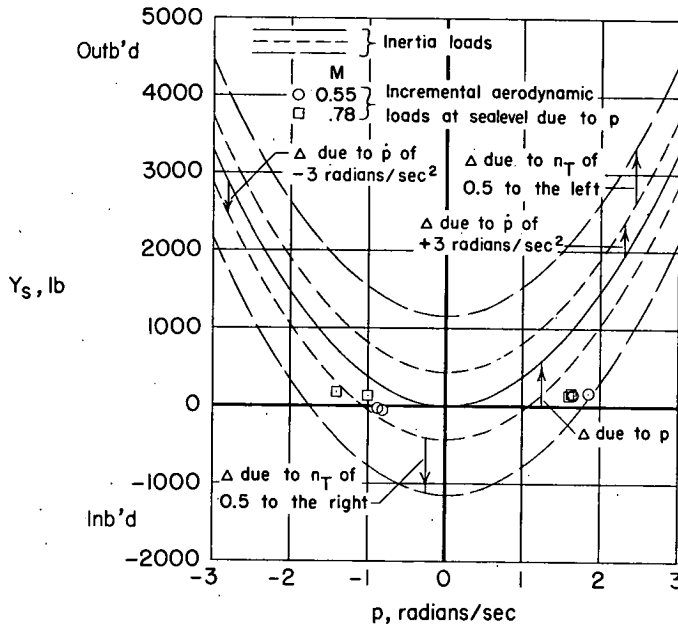
Figure 19.- Incremental overall force and moment coefficients at an altitude of 30,000 feet on right store, fins, and pylon due to airplane rolling velocity at two Mach numbers.

(a) Normal load.

(b) Side load.

Figure 20.- Comparison of inertia and aerodynamic effects on right store
   normal and side loads during rolls at sea level. Weight of store
   and fuel, 1,450 pounds.